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Fragility Analysis of Regular Multi-Storey RC Building

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ABSTRACT

The aim of this study is to determine fragility curve for a five, seven and eight storey building designed on basis of Indian Standard code 456:2000. Fragility curves were developed with respect to spectral acceleration (S_a) and spectral displacement (S_d). Non-linear static pushover analysis was performed and the ground motion parameters S_a and S_d were obtained that satisfy the Limit of Safety (LS) and immediate occupancy (IO). A comparison is carried out for fragility with variation in number of stories and also, variation of different reinforcement by considering Fe-415 and Fe-500 reinforcement in the design of bare frame structure.

Keywords: Fragility Curve, non-linear static procedure, non-linear dynamic procedure, immediate occupancy, limit of safety

I. INTRODUCTION

Non-Linear dynamic analysis though reliable is a very time consuming process. However, pushover analysis is a quick and simplified approach which can be accounted for development of analytical fragility curves and can be further compared with experimental or empirical ones. Fragility analysis for seismic failure of a building is a very useful concept for important structures like hospitals, educational building, structures important from archaeological point of view, as well as also for multi-storey buildings and bridges. The details about structural damage along with probability varying from yielding of the structure to its collapse can be obtained from fragility analysis Different methodologies were developed to show fragility relationship between intensity measure and response of building. These methodologies are classified into four types which are as follows: experimental, analytical,empirical and hybrid fragility curves.

1) Empirical Fragility Curve:
These are constructed based on field observation. These curves are formed on basis of damage data, ground motion intensity distribution. Damage reports are utilized to establish relation between ground motion intensity and damage state of each building.

2) Experimental Fragility Curve:
These curves are developed based on opinion or expert data collected when sufficient data was not available for probability of building damage. Applied Technology Council (ATC) developed first experimental fragility curve in 1985.

3) Analytical fragility Curve:
These curves use numerical simulation to predict damage distribution. For complex building analytical method is prefered to create fragility curves.

4) Hybrid Fragility curve:
These curves are based on combination of experimental, analytical and empirical fragility curves and give more realistic fragility curve. Due to insufficiency of data for empirical, experimental method and complexity of building modelling in empirical method, this method was adopted.

II. METHODOLOGY

Developing fragility curves for a specific type of building is a probabilistic method to estimate the probability that the building will exceed a specific state of damage for a definite value of the seismic intensity parameters. Seismic fragility analysis can be used to evaluate the performance and vulnerability of structures under earthquake events. It plays an important role in estimating seismic losses and in the decision making process based on building performance during seismic events. To build seismic fragility curves, structural capacity limit and demand models are needed. Fragility curve depicts the probability of structure damage as a function of ground motion intensity measure (IM) such as spectral displacement (S_d), peak ground acceleration (PGA) or any other intensity measure

The effectiveness of pushover analysis and its computational simplicity brought this procedure to several seismic guide lines (ATC 40 and FEMA 356) in recent years. The pushover analysis procedure can be used for checking the applicability of the new design of the structure. To develop analytical fragility curve the details are presented as below:

A. Description of structure

In the present study bare frame structure of 5, 7 and 8 storey regular RC building is considered for analysis. The following are the details of the chimney considered:

1) Size of beam – 300*400
2) Size of column – 400*400
3) Plan area – 16m * 12m
4) Grade of concrete – M25
5) Grade of steel – Fe415 and Fe500
6) No. of bays in x-direction - 4
7) No. Of bays in y-direction - 3
8) Slab thickness – 150mm
9) Type of soil – type 2,medium (As per IS : 1893)
10) Depth of foundation in ground – 3.1m
11) Building importance factor – 1
12) Response reduction factor – 5

B. Model generation

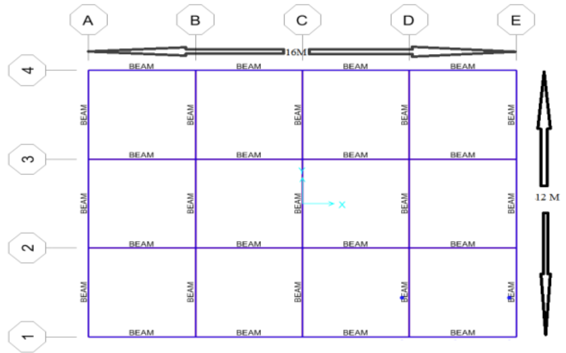


Figure1: Plan of regular building model

C. Load calculation

The dead loads applied on the structure are as follows:

1) Load on outer wall = 0.23*3*20 KN/m = 13.8 KN/m
2) Load on inner wall = 0.15*3*20 = 7.2 KN/m
3) Load on Parapet wall = 0.23*1*20 = 4.6KN/m

The live load applied is 3KN/m^2 on typical floor, however the live load provided is 1.5 KN/m^2 on terrace.

D. Seismic Evaluation by using Sap 2000

Non linear static pushover is used to evaluate the expected performance of structural system by estimating its strength and deformation demands. The model is subjected to monotonic unidirectional push. The hinges developed are auto-defined according to FEMA356 (2000). Two key element of a design procedure are based on performance, demand and capacity. The demand is a representation of earthquake. Capacity is a representation of the structure's ability to withstand seismic demand of pushover analysis procedures. The performance depends on the lack of capacity to handle the demand. Three dimensional model which includes bilinear or tri linear load-deformation diagrams of all lateral force resisting elements is first created and gravity loads are applied initially. For that predefined lateral load pattern which is distributed along the building height is then applied. The lateral forces are increased until some members yield. This process is continued until a controlled displacement at top of building reaches to a stage when structure become unstable or reaches certain level of displacement.

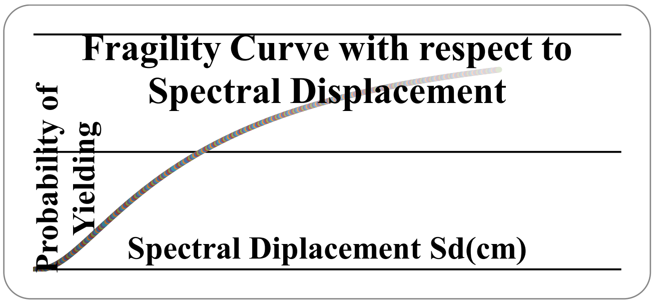
E. Fragility curve derivation

- On basis of the pushover method parameters S_d and S_a are obtained in form of capacity spectrum analysis curve and tabulated form.
- The values of ground motion parameters spectral displacement (S_d) and spectral acceleration (Sa) are exported to MS Excel.
- Based on the formula for fragility function, the above values are provided as input to obtain probability in form of output and plotted on graph.

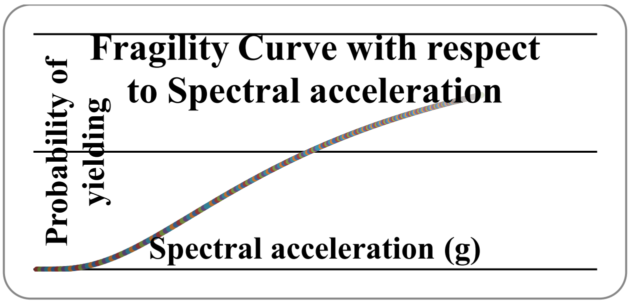
III. RESULTS AND DISCUSSION

A. RESULTS

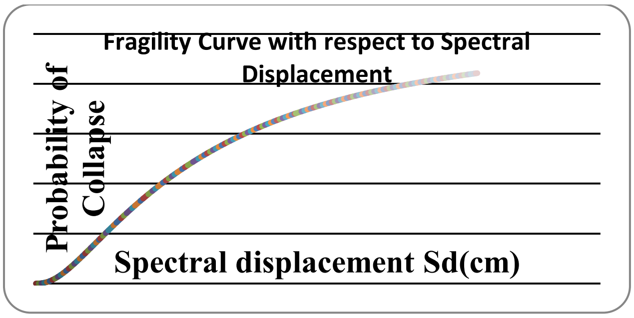
1) Fragility curve for 5storey building for Fe-415 reinforcement with spectral displacement as ground motion parameter :



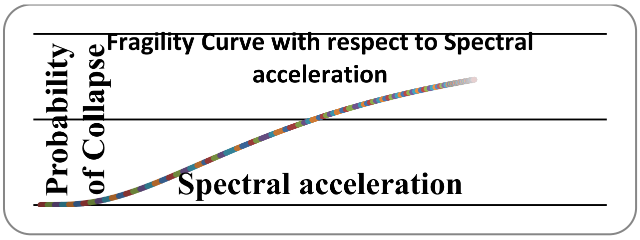
2) Fragility curve for 5storey building for Fe-415 reinforcement with spectral acceleration as ground motion parameter :



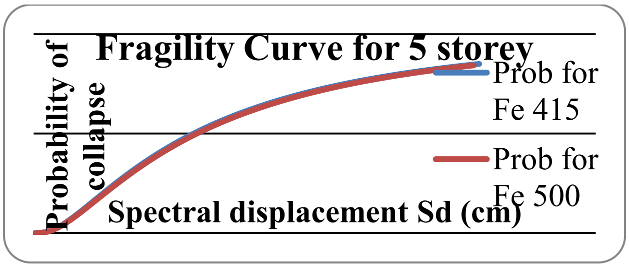
3) Fragility curve for 5storey building for Fe-500 reinforcement with spectral displacement as ground motion parameter :



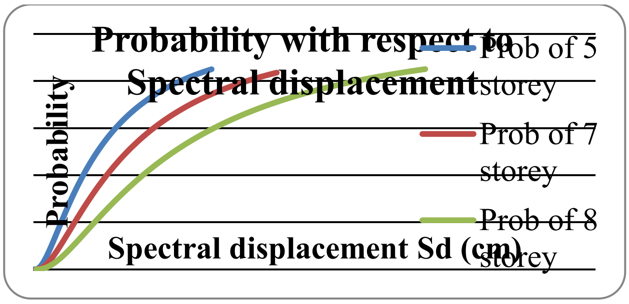
4) Fragility curve for 5storey building for Fe-500 reinforcement with spectral acceleration as ground motion parameter :



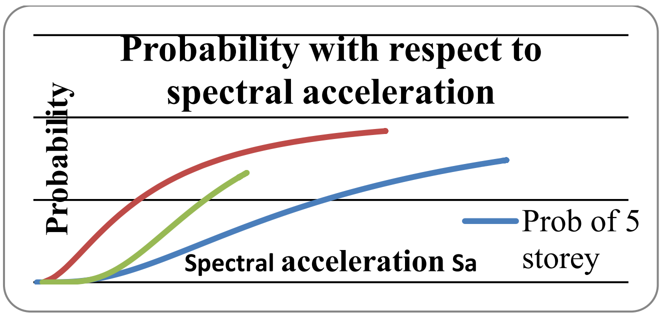
5) Comparison with respect to spectral displacement for reinforcement Fe415 and Fe500



6) Storey wise comparison :with spectral displacement as ground motion parameter



7) Storey wise comparison : with spectral acceleration as ground motion parameter



B. DISCUSSION

The probability of structure reaching upto yield point is more than probability of collapse of structure. Mostly, for all the bare frame structures of five, seven and eight storey the probability of yielding lies in range of Immediate Occupancy (IO) to Limit of Safety (LS).The fragility parameters, mean and standard deviation obtained are found to vary with the change in no. of stories. Since, the probability of yielding of non-structural components and structural components is much more than collapse ,therefore the probability of yielding have gone above 0.6 with respect to spectral acceleration and spectral displacement. With the increase in no. of stories, the probability of yielding goes up for spectral displacement.

IV. CONCLUSION

The fragility curve, a probabilistic distribution of failure is developed with respect to ground motion indices like spectral displacement and spectral acceleration for 5storey, 7storey and 8storey RCC building. Damage states for building failure are defined on the basis of definition provided by ATC-40. The following points are concluded based on the curve obtained:

- The probability of yielding for all the structures are found to lie in the range of IO (Immediate Occupancy) to LS (Life Safety).
- The probability of yielding of building reaching to slight or moderate damage has reached to 91% at the maximum.
- Increment in no. of storey leads to reduction in the probability of yielding for spectral displacement.
- The probability of yielding shoots up with no. of storey for spectral acceleration.
- A consideration of fragility curves for different reinforcement Fe415 & Fe500 is performed which requires further research.
- With respect to Spectral displacement it is found that 5storey building is more prone than 7storey and 8storey building
- A consideration with respect to spectral acceleration results that 7storey building is more prone than 5storey and 8storey building, with 5storey is the least prone.
- Juxtaposition for Fe415 & Fe500 reinforcement of 5storey building it is found that probability of yielding almost coincide with respect to both parameters Spectral displacement & Spectral acceleration.
- Illustration for Fe415 & Fe500 reinforcement of 7storey building it is found that probability of yielding almost coincide with respect to Spectral displacement .However, with respect to Spectral acceleration building with Fe415 is more prone than with Fe 500.
- An analogy for Fe415 & Fe500 reinforcement of 8 storey building it is found that probability of yielding is more prone for Fe500 than Fe 415 with respect to spectral displacement.
- Probability of yielding is more for Fe500 upto 0.026 spectral acceleration than Fe415 and vice versa after 0.026 spectral acceleration for 8storey building.
- The procedure provides computational efficiency and a quick way for development of fragility curve, however needs to be supplemented with further studies.

The results and conclusions drawn from this fragility analysis are applicable only to the structures under consideration along with the same soil conditions and same zone factor.

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